Pilgrim Trust Lecture

Organization of American scientists for the war

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Introduction

In ordinary times any American scientist would deem it a distinguished honour to be nominated as the Pilgrim Trust lecturer. In these extraordinary times the significance of this lectureship is enhanced by the fact that American and British scientists are working hand in hand, not only to advance science as an important aspect of man's culture, but now especially as a powerful tool for the preservation of our opportunities for continued life, liberty and pursuit of happiness. Consequently, when Sir Henry Tizard transmitted your invitation for me to deliver this lecture I accepted the invitation with profound appreciation and humility.

There were also two personal aspects of this invitation which aroused in me a sentimental reaction. The establishment of the Pilgrim Trust lectures was announced to the Royal Society by your late colleague, Sir William Bragg, in his presidential address at the anniversary meeting of the Society in 1937. Not only has Sir William Bragg, together with his distinguished son, been an inspiration to my generation of American physicists, but it happens that he delivered the address at the Graduation Exercises of the Massachusetts Institute of Technology on the occasion of my inauguration as president of that institution in 1930. I recall very vividly his remarks on that occasion and my feeling that his presence was an inspiration to me at that time when, with considerable trepidation and regret, I moved from the research laboratory into an administrative office.

In that address Sir William traced the development of modern institutions for technical instruction and drew his illustrations from the lives and work of Count Rumford, Thomas Bernard and Michael Faraday. Permit me to read several excerpts from Sir William's address.

'A school of technology is an expression of the wish to gather together the growing knowledge of nature, of natural materials and laws, and to make that knowledge of service to mankind.... Where and when did this movement begin? It is not of great antiquity. Perhaps the seventeenth century includes its first recognizable appearance, marked by the new-found delight in careful experimental examination of the world. The Royal Society of London was founded in the troubled times of conflict between King and Parliament: where we read the account of the early proceedings of the Society we are reminded of boys let out of school, running quickly to brook and hedgerow to examine the extraordinarily interesting things

to be found there at every turn. A very important account of the methods of ventilating mines in Belgium comes next to the careful description of some animal monstrosity such as a calf with more than the proper allowance of heads or legs. The professor of astronomy at Oxford writes on the use of incubators in Egypt. Early discussions on tide prediction, then a very important matter because the old harbours did not easily accommodate the large boats wanted for the American trade, lie side by side with a disquisition on a remarkable set of teeth and pertinent references to the properties of sugar. The hodge-podge is readily understandable. The infant was beginning to notice and ask questions.... We can well be amused at all this, remembering that the infant has now become a very sturdy youth: and that the proceedings of these early fellows of the Royal Society were only the first results of the new regard for natural knowledge.'

Sir William then proceeded in most interesting fashion to sketch the significant facts in the life, work and social viewpoint of Count Rumford and Thomas Bernard, and pointed out that the wealth of Bernard and the stimulation given by Benjamin Thompson, both of them men who spent their early lives within a few miles of my home in Massachusetts, led to the establishment of your Royal Institution.

Then, after drawing lessons from the life of Michael Faraday, Sir William concluded with these words:

'Science was not merely a collection of inventions to be applied by the rich for the comfort of the poor. It was a glorious purpose to be shared by all mankind. We must try to understand the world in which we live, for our own enjoyment, for the training of our minds, for the enrichment of our souls' contemplation, for the means whereby we may help each other. It is in this spirit that we may try to do our work. It is true of course that we must work for ourselves, instructors have to earn their living and students must come to learn how to earn theirs. As the world is made it must be so, but also the world is so made that the vision of its wonder and of the delight of mutual service and the happy task of exploring the one to help us in achieving the other, can light our lives for us as the sunshine lights the earth.'

As we think of the noble ideals which Count Rumford, Thomas Bernard and Michael Faraday held for science as that which 'can light our lives for us as the sunshine lights the earth', it is a grim and discouraging contrast to see the scientists of the world engaged to-day in developing new instrumentalities for destruction or other instrumentalities for protection against the destruction which would be wrought upon us by the engines of war of our enemies. The fact that this is so is a grim reminder that our skill in statesmanship and our art and ethics of Christian living have not kept pace with our ideals. We have no alternative now but to apply our knowledge of science in every aspect to serve us in our struggle for survival and to preserve for us that opportunity for which our race has struggled throughout the centuries—the opportunity to live and work in peace and freedom.

As the second personal note, let me lay claim to scientific kinship with your body as one who might be called a scientific grandchild of another one of your late

leaders, Sir Joseph Thomson. We in America affectionately called him 'J.J.', as I understand you also did in England, and we look upon him as the progenitor of that tribe of physicists who interested themselves in the conduction of electricity through gases. Taking him as the founder of that tribe, one of the second generation, your Sir Owen Richardson, was my guide and inspiration during my graduate student years at Princeton University. For his sake I am sorry that I did not turn out to be a more productive pupil, but the interests and satisfactions I have had in the field of research I owe more to him than to any other man.

As you know, we in America have two principal scientific societies which are broadly representative of all the fields of science and which are rather parallel to two of your principal scientific bodies, the Royal Society of London and the British Association for the Advancement of Science.

Dr Frank B. Jewett, President of our National Academy of Sciences, has asked me to deliver his personal message to the President of the Royal Society of London, Sir Henry Dale, and in addition he requested me to express to you the admiration which is felt by the members of the National Academy of Sciences for the magnificent manner in which the scientists of Great Britain have thrown the whole weight of their energies and abilities to master the innumerable technical problems arising in this war. He wanted me to assure you that in so far as we can do likewise, we in America are making a sincere effort to handle our similar problems and co-operatively to supplement the great work which you are doing.

Dr Isaiah Bowman, last month elected president of the American Association for the Advancement of Science, also gave me a message of greeting to British scientists from which I quote as follows:

'Now that the war has advanced to the stage at which we begin to talk of post-war plans, we feel more than ever the need for collaboration between Great Britain and the United States. While there is no such thing as an Anglo-American bloc in world politics there is such a thing as close comradeship in the fight for principles. This comradeship we feel whenever we deal with the leaders of Britain and whatever the field of interest. I venture to predict that, whatever difficulties may arise, we shall find that comradeship and agreement upon principles will ever mark our future relations. This belief is based upon our widely recognized common responsibility for the peace and safety of mankind in the years after the war. If England is being changed by the war the United States is changing just as rapidly. Once our President was able to report on "the state of the Union", as our Constitution provides, almost without touching on foreign affairs. Two world wars have changed both the tenor and the scope of such messages. The state of the Union now includes the state of the world. This conception of the state of the Union lays new obligations upon us all. The scientist can no longer report on the state of the sciences. He must report on the impact of science upon society. He must make use of the qualities of mind that science fosters in dealing rationally with the terrible waste in vital resources that war imposes upon the human species. We may hope that the day will soon come when every mature man and woman

will feel himself responsible for the state of the Union and act responsibly in that sector of our common life committed to his care, no matter how small the sector may be, no matter how humble.

'We say these things while recalling again how great an inheritance they represent from the unfolding political life of Great Britain. No one can speak of liberty and political responsibility and community enterprise without echoing truths that were discovered by centuries of experiment and experience on the part of rulers and ruled in the English political system. Thus, no matter where one starts in estimating future problems and future responsibilities, one ends by recognizing the special bond between America and Britain, by acknowledging the rich inheritance that has been responsible for so many strong elements in American life, and by elevating the comradeship that we both feel and need.'

And now I come to the subject of my address. I have chosen to speak on a subject pertinent to the war, to describe to you the manner in which American scientists have organized to make their contribution to the same cause which has mobilized your efforts. In so doing, I trust that I shall be within the spirit, if not the letter, of Sir William's directive for these lectures. For he said, 'Such lectures would associate workers in a common task', and surely our common task right now is to direct our scientific resources for victory.

In these days, when numbers of scientists are crossing the Atlantic in both directions on special missions, a better understanding of each other's organizations may be practically helpful. For I frankly confess sympathy with one of your number who recently told me that he found the American organization of interrelated scientific groups a bit complicated. I can only draw cold comfort from the fact that, complicated as it is, the scientific organization is far simpler than that of our governmental departments and bureaux generally. But that is another story.

Peace-time organization of scientists in the U.S.

Let me first give an over-all picture of the scientific and technical organizations of the United States as they exist in peace-time. After this brief review I shall pass to a discussion of the special scientific organizations for war, which is the subject of more particular interest to us at this time.

The scientific and engineering work in the United States may be discussed under three categories: first, the agencies of the Federal Government, exclusive of the Armed Services; secondly, the agencies within the Armed Services; and thirdly, the non-governmental agencies.

Federal Bureaux. The scientific services of the Federal Government in peace-time are spread through about forty federal bureaux, of which eighteen can be called primarily scientific. Their operations involve only about half of 1% of the total peace-time federal budget, but their work is absolutely essential to the national welfare in agriculture, manufacture, commerce, health and safety. The personnel of all these bureaux operates under the Civil Service.

From the point of view of size of personnel and budget, the scientific services under the Department of Agriculture stand first in the list. Probably these scientific establishments, however, are not as well known generally as those of some of the other departments because their research work is quite largely spread through a great number of agricultural experimental stations distributed throughout the various states of the Union and operated co-operatively between the Federal Government and the States. Most of the bureaux in Washington are primarily of an administrative character, but there are several which also conduct centralized research, as, for example, the Bureau of Chemistry and Soils and the Food and Drug Administration. Until recently the U.S. Weather Bureau operated under the Department of Agriculture, but a few years ago it was transferred to the Department of Commerce, largely because the requirements of air transportation had taken the lead in demanding more accurate and refined methods of weather forecasting than those which had served reasonably well in the past to provide for the needs of agriculture.

Many of you will probably recognize some of the more important of these governmental scientific bureaux, as, for example, the National Bureau of Standards under the Department of Commerce, the Geological Survey, the Bureau of Mines, the Bureau of Mineral Statistics and Economics under the Department of the Interior, and the National Institute of Health under the U.S. Public Health Service.

Of particular interest because of its unique character is the National Advisory Committee for Aeronautics which was established during the last war and which operates three great research establishments. Until recently the work of the N.A.C.A. was centred in the aerodynamical research programme at Langley Field, Virginia. Several years ago there was added another aerodynamical research establishment named the 'Ames Laboratory' at Moffett Field, in California, and quite recently still another large research and development establishment for aircraft engines in Cleveland, Ohio. Also, under the N.A.C.A., there are currently some eighty research projects being carried on at universities under contract. This obviates unnecessary duplication of facilities in a government laboratory and maintains a group of university scientists and engineers in close contact with the problems of aeronautical research.

The administration of this organization is also unique among our federal scientific agencies in that its controlling body is a committee which serves without salary and has been composed of men of such high character and distinction as to render it completely free from political influence. This committee is provided with representation from the most interested branches of the Army, Navy and Governmental Departments, but the chairman and the majority control reside in a body of citizen scientists appointed by the President who, in practice, has followed the recommendations of the chairman in appointments to fill vacancies. The present chairman of the N.A.C.A. is Professor J. C. Hunsaker, head of the Departments of Mechanical and Aeronautical Engineering at the Massachusetts Institute of

Technology, and incidentally, while a very young man, the designer of the first American airplane to fly the Atlantic.

Turning now to the United States Armed Services, I can best describe their research and development work as principally a co-operative effort between the services themselves and American industrial companies, with occasional participation from the research laboratories of the technological and educational institutions.

Army. Each branch of the Army contains a technical division under which operate laboratories or arsenals in which a certain amount of research and development work is carried on, but whose activities consist for the most part of testing and proving new war materials or equipment. Thus the technical staffs in the various branches of the Army and Navy have the threefold duty of planning and co-ordinating an extensive programme of research and development carried on in the industrial laboratories, of organizing and conducting research programmes in their own establishments, and of carrying on the extensive operations of proving and testing which result in the acceptance of new devices and the drafting of specifications for production orders.

Among the principal Army establishments in which such work is centred, I would mention particularly those falling under the Ordnance Department, the Signal Corps, the Chemical Warfare Service, and the Army Air Forces. The Ordnance Department operates a great proving ground at Aberdeen, at which is centred most of the proving and testing of ordnance and research on ballistics for arms of all types. In addition it operates five principal arsenals. The Watertown Arsenal is concerned principally with the manufacture of mounts for large-calibre guns and is the principal centre for research and technical service in the field of metallurgy. The Picatinny Arsenal is devoted to the testing of explosives and the design and operation of pilot plants as guides to the industrial producers. The Rock Island Arsenal carries on research and development in the field of oils and lubricants. The Frankford Arsenal supplements the Aberdeen Proving Ground as a testing and a development centre for small arms. The Tank Arsenal in Detroit is the centre for the design and testing of tanks.

In the Signal Corps the technical division is divided into three principal branches: the Ground Signal Branch, the Electronics Branch and the Aircraft Radio Branch. The research, development and testing work carried on under the Signal Corps is divided principally between the signal laboratories at Fort Monmouth, Camp Evans, Camp Coles, Eatontown, and Toms River. The Signal Corps also maintains a large co-operative establishment working with the Army Air Forces at its principal centre, Wright Field.

Until quite recently the research and development work of the Chemical Warfare Service was centred in its great Edgewood Arsenal. As the threat of war came closer, however, a few years ago, and since a very large portion of the facilities at the Edgewood Arsenal are taken up by production, the Chemical Warfare Service established a subsidiary research laboratory and took over for this purpose the

newly erected Chemical Engineering Laboratory of the Massachusetts Institute of Technology.

Despite the great expansion of the Army Air Forces, this service has continued to concentrate its research, development and testing activities at its huge establishment at Wright Field in Ohio. There are of course many other centres at which extended service testing goes on, or at which new equipment is installed in aircraft, but Wright Field remains the headquarters for the research and development work of the Army Air Forces.

The co-ordination among all these various technical services of the Army is maintained by two types of agency. Within each branch of the Army is a Board which has general supervision over technical matters within that branch. Examples are the Coast Artillery Board and the Army Engineers Board. When a project has been approved by one of these boards it is next discussed by the appropriate Technical Committee, composed of members of this branch of the service, and other branches which may be concerned with the project. If this Technical Committee also approves the project it goes as a recommendation to the general staff which presumably issues the appropriate directive.

Mention should be made also of the Army Medical Corps, within which a significant amount of research is conducted under the general supervision of the Surgeon-General of the Army.

Navy. The Naval Observatory and the Hydrographic Office, which are under the Chief of Naval Operations, have obvious functions in research and development work. The Marine Corps does some research, but naturally depends to a large extent on the Army and the various Bureaux of the Navy. All the Bureaux of the Navy Department, Ships, Ordnance, Aeronautics, Naval Personnel, Supplies and Accounts, Medicine and Surgery, Yards and Docks, do research and development work, though naturally the matériel Bureaux conduct the greatest volume.

All research work of the Navy Department is tied together through the office of the Co-ordinator of Research and Development, which office also arranges co-ordination with the Army, with other government departments, and with the numerous civilian agencies which I will mention later.

Under the Bureau of Ships the Naval Research Laboratory near Washington is a centre for all matters of fundamental research including radio, electronics, chemical warfare defence, etc. The David W. Taylor Model Basin, also near Washington, is the primary station for research and development of ship structures, propeller and hull design. The Naval Boiler and Turbine Laboratory at Philadelphia is concerned with all matters of boiler research, testing and design including fuel, composition, quality and nature of boiler fuels, ceramics, etc., and also for research, test and development of main propulsion turbines. The U.S. Naval Engineering Experiment Station at Annapolis, Md., is assigned all problems of research, test and development of mechanical equipment in ships other than main propulsion, and it also has a well-equipped Diesel-engine laboratory. The principal metallurgical laboratory for the Bureau of Ships is also located at the Engineering

Experiment Station. In New York there is located the Materials Test Laboratory which handles all matters of research, test and development of electrical materials and equipment, acoustical equipment, optical and navigational material and equipment, plastics and allied materials. There are Rubber and Paint Laboratories at Mare Island, California, and an inspection test laboratory in Pittsburgh, Pa., where line-production methods for chemical analyses are set up which permit a capacity of about 5000 chemical analyses per week with a minimum of personnel and equipment. In addition to the above each Navy Yard is equipped with an industrial laboratory to serve the purposes of the Yards. It has been found possible to place specialized problems in some of these laboratories such as the development of chain and rope in the Boston Navy Yard. The assignment and progress, as well as general administration of all research, development, and test work, is carried out by the Bureau of Ships in Washington in order most fully and effectively to co-ordinate all work and to collect, apply, and distribute the results.

Under the Bureau of Ordnance there are the Dahlgren Proving Ground, the Naval Gun Factory at Washington, whose research department includes the Naval Ordnance Laboratory, the Naval Powder Factory near Washington, and the Newport Torpedo Station. In addition there are establishments devoted to mines, counter-mines, nets and the like.

Under the Bureau of Aeronautics there is the Naval Aircraft Factory in Philadelphia, the Cedar Point Flight Testing Field near Washington, and the Aircraft Armament Laboratory and Testing Field at Hampton Roads.

Research in medicine and surgery is directed by the Research Division of the Bureau of Medicine and Surgery, using many facilities but largely those of the U.S. Naval Medical Research Institute at Bethesda near Washington, and the Medical Research Laboratories at Pensacola and New London.

Civilian agencies. I pass now to the non-governmental scientific organizations in the United States, most of whose members are attached to the staffs of some 600 colleges, universities and engineering schools, some 2000 industrial research laboratories, and other specialized research institutes. Do not be alarmed when I begin by saying that these comprise well over one hundred nationally recognized scientific and engineering societies, exclusive of the social sciences. Of these, only a few are general in scope in the sense that they cover broadly the entire field of science. Largest of these is the American Association for the Advancement of Science, a close parallel to your British Association, with a direct membership of about 24,000 and an indirect aggregate membership of about a million through the 187 associated and affiliated societies. Of a more exclusive character and without the affiliated and associated societies are the American Philosophical Society and the American Academy of Arts and Sciences.

Unique among the scientific organizations of the United States is the National Academy of Sciences. In March 1863, during a crisis of our Civil War, Congress established the National Academy of Sciences, and President Lincoln signed the Act of Incorporation. This Act specified that 'the Academy shall, whenever called

upon by any department of the governments, investigate, examine, experiment and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments and reports to be paid from appropriations which may be made for the purpose'. There was also the provision in the charter that, except for the actual expenses of these activities, neither the Academy nor any member of the Academy is entitled to receive any compensation whatsoever for such services. Although the membership is legally limited to 450, the actual membership in the Academy has never exceeded its present enrolment of 350.

Outside of its services in war-times, perhaps the most noteworthy public service by the Academy was its geological and engineering investigation of the slides which at one time threatened to prevent the successful consummation of the Panama Canal. However, the utilization of the Academy by the government has been rather 'spotty'. Under some administrations the Academy has been used rather extensively, and in other administrations has been more or less forgotten by the government. In this respect I believe that your Royal Society has had a more consistent role of usefulness.

One inevitable characteristic of this type of organization, in which membership is considered to be the highest scientific honour of the country, is that membership, like scientific recognition, is likely to come to a man after he has passed the peak of activity in his scientific career. For this reason the Academy has been able to perform an excellent function of the 'scientific elder statesmen' variety. It has zealously kept itself free from all types of political influence. Its ideals have been unselfish service, integrity and scientific competence. Frequently, however, probably in the great majority of cases, when a very active research programme has to be undertaken, many of the personnel best adapted for the particular job are not found within the membership of the Academy.

During the last world war in Europe, but before the United States had become a participant, President Wilson by executive order requested the National Academy of Sciences to establish the National Research Council as a measure of national preparedness. This organization operated so usefully during the war that after its termination, in April 1919, the National Research Council was perpetuated by the National Academy of Sciences at the express request of President Wilson

This National Research Council is organized into nine permanent divisions covering the various fields of scientific research and of scientific administration. These divisions are composed of appointed members and also of representatives from many of the scientific and engineering societies and branches of the government. Because of this wide representation the National Research Council is a most effective agency for finding just the right persons to do any specific scientific job.

During the present war the National Academy and the National Research Council have been called upon to perform many important services, some of an advisory character and some involving the placing of contracts for research and development work in various laboratories.

Among the nearly 200 committees operating under the National Research Council, the following are typical of those concerned with the war: Aviation Medicine, War Metallurgy, Passive Protection against Bombing, War Use of Research Facilities, Tin Smelting and Reclamation, Clothing, Shock and Transfusions, Treatment of Gas Casualties, War-time Diet, and Selection and Training of Service Personnel.

War-time scientific organization

In spite of the apparently complete peace-time organization which I have just described, it has always been our experience, in the time of great emergency, that it appears advisable to establish temporary new agencies to deal particularly with the emergency. For example, I happened to be attached to one of these temporary agencies during the last war, and I mention the matter not only by way of illustration but also because it will enable me to relate an anecdote about your late distinguished colleague, then Sir Ernest Rutherford.

This agency was the Research Information Service, set up jointly by our Military Intelligence, Naval Intelligence and Council of National Defence, with offices in Washington, London, Paris and Rome. The function of these offices was essentially the same as that of the Scientific Liaison Offices which have been operating so effectively between units of the British Commonwealth and the United States during the present war.

The head of the Research Information Service in London was the late Professor Bumstead whom some of you doubtless remember. I was attached to the Paris office and happened to be temporarily in charge during the time when an allied conference on submarine detection was arranged in Paris under the auspices of this office.

One of the delegates from Great Britain was Sir Ernest Rutherford who had been collaborating closely with the French physicist, Paul Langevin, in the development of underwater supersonic devices. The day before the conference, when the British and American delegations came over from London, Rutherford was not present but he sent me a letter, delivered by Professor Bumstead, stating that some very recent experiments which he and his research assistant had been carrying on in the Cavendish Laboratory had apparently indicated success in disintegrating the nucleus of the hydrogen atom. 'If this is true', Rutherford wrote, 'it is a fact of far greater importance than the war.' He went on to say that he was in the midst of a second experiment to check these startling findings and that he would be delayed a couple of days pending the termination of this experiment. Then Rutherford added as a postscript: 'Tell nobody about this because I may be mistaken.' Later it developed that what Rutherford had actually done had not been to disintegrate the hydrogen nucleus, but rather to disintegrate the nuclei of nitrogen atoms. So far as I know, Rutherford's letter to me was the first written indication of success in the long, long struggle to produce by artificial means a transmutation of one chemical element into another. I wish I had kept that letter

and had turned it over to Professor Eve at the time when he was writing his interesting biography of Ernest Rutherford. But to return to our topic.

I have frequently tried to analyse the reasons for the establishment of special scientific agencies during times of crisis. The reasons I think are varied and rather fundamental. One of them is that every great crisis involves conditions so different from the normal situation that the types of organizations which can survive and operate during peace-time are not adequate to meet the emergency. It may be, for example, that the emergency calls for exercise of very extensive administrative functions, such as the supervision of research projects and the disbursement of large governmental funds to a far greater extent than in peace-time. Hence a peace-time body of scientists organized primarily to exercise advisory functions may not be organized in a manner suited to prompt and efficient executive action. Another reason is the impossibility of always maintaining in the administrative positions of peace-time agencies the personnel who would be most effective for handling important projects in a war emergency. Men who have the proper capabilities are frequently too busy and too active in other directions to be willing to hold down positions in a peace-time organization which is relatively inactive. Consequently when the emergency comes, the only alternatives may be to change the leadership in the existing organizations, a difficult if not impossible process, or to set up new temporary agencies to deal with the emergency.

Whatever the reasons may be, this present war emergency has run true to form and has resulted in the establishment of a group of special agencies of temporary character which I shall proceed now to describe. It is these agencies which are carrying the principal burden of the scientific research and development work related to the war, in the United States.

The National Roster of Scientific and Specialized Personnel was established early in July 1940, when President Roosevelt approved a project for making available in one central office an index of all American citizens who have special scientific or professional skill. Headed by President Leonard Carmichael of Tufts College, this agency operates under the War Man-power Commission under the Office for Emergency Management of the executive office of the President. As a result of information secured from questionnaires sent to all members of all scientific and professional organizations in the country, and supplemented by other information, an elaborate punch-card system has been set up in which practically every person in the country with specialized training or skill is listed with reference to his or her major professional fields and with the addition of a great deal of supplementary information regarding special interests, languages read or spoken, foreign countries travelled in, previous experience in the armed services or in industry, etc.

There are altogether fifty-nine special fields listed in the roster, falling under the general categories of administration and management, agricultural and biological sciences, engineering and related fields, humanities, medical sciences and related fields, physical sciences, and social sciences. At the present time the total number

of persons in this roster is about 600,000, including, in October last, 71,511 chemists, 7297 mathematicians, 10,080 physicists or astronomers, 4559 radio engineers, 14,729 electrical engineers, only 408 professional philosophers, and the smallest entry in the list is 142 speleologists.

As an illustration of the manner of use of this roster I quote the following paragraph from a report by Dr Carmichael:

'How would you like to get an order for the names of all Americans who possess a knowledge of epidemiology and chemotherapy, who are competent in the diagnosis and control of *Endamoeba histolytica*, and other protozoan infections, have a knowledge of the Hindustani language, are skilled in the operation and use of specialized bacteriological research apparatus and who have travelled in the tropics?' To secure this information the stops of the punch-card sorting mechanism are pushed in at the appropriate places, the cards are ground through the machine, and all of those which conform to the above specifications fall out together.

The roster was originally conceived to serve governmental agencies who might request information on scientific personnel. More recently, as serious man-power shortages have developed both in industry and in education, and as the armed services have become more and more concerned over the most effective use of all scientifically trained personnel, the roster has been used to an increasing degree in connexion with placement work and to give the supply and shortage data on professional groups. Up to the middle of last month the National Roster had certified more than 140,000 names of specialists to various agencies engaged in the war programme in the United States.

Office of Scientific Research and Development (*O.S.R.D.*). Most important of the scientific agencies established specially to deal with problems of this war is the Office of Scientific Research and Development, whose Director is Dr Vannevar Bush, President of the Carnegie Institution of Washington. It was created by executive order of the President in June 1941, and under it operate the National Defence Research Committee, which had been established just a year earlier, and also the more recently established Committee on Medical Research. The O.S.R.D. is directed to co-ordinate, and where necessary supplement, the scientific research and development work relating to the war among civilian agencies as well as those of the government, including the Armed Services. To facilitate this co-ordination the advisory council to the Director of O.S.R.D. includes high-ranking representatives from the War and Navy Departments, the Chairmen of the National Advisory Committee for Aeronautics, the National Defence Research Committee and the Committee on Medical Research, and, by invitation, the President of the National Academy of Sciences and the Director of the newly established Office of Production Research and Development of the War Production Board.

The principal research and development activities of the O.S.R.D. are carried on under contracts with appropriate research institutions, these contracts being financed out of an annual Congressional appropriation. At the present time these contracts involve expenditures at the rate of about $100,000,000 per year, and

there are currently active about 1400 contracts with about 200 industrial laboratories and 100 educational or special research institutions. About 6000 scientists and engineers of professional grade are engaged on these contracts, with the assistance of a considerably larger number of technicians of various types.

To facilitate interchange of information between O.S.R.D. and our British colleagues, an O.S.R.D. Liaison Office was established with offices in Washington and London, now headed by Dr Caryl P. Haskins and Mr Bennett Archambault, respectively. These, in co-operation with the similar liaison services of Great Britain, Canada and, less extensively, Australia and South Africa, have served well to knit together our joint scientific efforts.

The National Defence Research Committee (*N.D.R.C.*) operates to recommend to the Director of O.S.R.D. research and development contracts in the field of instrumentalities, devices and mechanisms of warfare. Under the chairmanship of President James B. Conant of Harvard University, this Committee is composed of four civilian scientists plus one representative each from the Army and Navy, and the Commissioner of Patents. Feeding into it come the recommendations from nineteen divisions, most of which are subdivided into several sections. These divisions and sections are each built around a specific functional concept such as fire control or subsurface warfare or explosives. However, there are two divisions which are in the nature of 'catch-alls'. For example, the Division of Physics and the Division of Chemistry can be defined as handling everything in these respective fields which does not fall under any one of the more sharply defined divisions.

In addition to the nineteen divisions of N.D.R.C. there are two panels concerned respectively with applied mathematics and engineering. The difference between a division and a panel is suggested by the fact that the Fire Control Division, for example, is concerned with the development of fire control instruments, whereas the Applied Mathematics Panel is not concerned with the development of applied mathematics as such, but rather with the use of mathematics to aid in accomplishing the objectives of the various divisions. For this reason the Applied Mathematics Panel includes membership on each divisional committee in which applied mathematics is likely to be important. The Engineering Panel serves all the divisions to expedite the transition from the stage of research and development to the stage of quantity production under Army or Navy contract.

Intimate contact between N.D.R.C. and its divisions on the one hand, and the Armed Services on the other, is maintained at several levels by an extensive organization of Army and Navy liaison officers who have proved invaluable as channels for acquainting N.D.R.C. with the needs and desires of the Armed Services for new equipment and for making arrangements for demonstrations and service tests.

Proposals for research or development projects come to N.D.R.C. from a wide variety of sources—requests or suggestions from the Army or Navy, proposals from industrial or academic research laboratories, promising inventions transmitted to N.D.R.C. from the National Inventors' Council, or in many cases

projects originating within the N.D.R.C. committees themselves. However, the N.D.R.C. has complete freedom in making its decisions on the projects which it recommends to the Director of O.S.R.D. and the priority attached to these projects, and the Director of the O.S.R.D. has complete freedom in his own judgement to authorize the recommended contracts.

For reasons of security no person serves as a member of any N.D.R.C. committee unless he has been 'cleared' by the Army and Navy Intelligence Offices, after investigation. Similarly, all personnel of the contractors working on the research and development projects are 'cleared' by these intelligence offices to whatever degree is deemed advisable in virtue of the degree of secrecy attached to the project.

The Committee on Medical Research (C.M.R.), under the chairmanship of Dr A. Newton Richards of the Medical School of the University of Pennsylvania, is in every respect parallel to the National Defence Research Committee in its organization and methods of operation. It deals exclusively with problems of war medicine, such as shock, immunization or protection against types of diseases characteristic of the present theatres of war, etc. Though considerably younger and smaller than N.D.R.C. in both personnel and budget, it already has a record of substantial accomplishment.

Joint Committee on New Weapons and Equipment (J.N.W.). The organizations described thus far have proven effective in organizing and administering research projects and in maintaining close relationships and exchange of information with the Armed Services and our British allies. In respect to the Armed Services, however, these relationships are primarily at the research and development level and for a time lacked one very important element necessary to make the work fully effective in the war. This missing element was an intimate relationship between the research and development agencies and the Highest Command of the Army and Navy who have the responsibility of planning the military or naval operations in which newly developed weapons might be used effectively or for which new devices should be developed. In order to fill this gap the U.S. Joint Chiefs of Staff in May 1942 established the Joint Committee on New Weapons and Equipment, composed of Dr Bush, Director of O.S.R.D., as Chairman, the Assistant Chief of Staff G4 of the Army (now Brigadier-General Moses) and the Chief of the Readiness Division of the Navy (now Rear-Admiral De Laney).

J.N.W. is charged by the Chiefs of Staff with correlating the research programme of army, navy and civilian agencies. It acts through subordinate bodies of which the special mission in which I am at present engaged in England is an example.

Through J.N.W. any new weapon whose potentialities appear to be unusually significant is brought directly to the attention of the High Command for their consideration in the planning of future operations. Conversely, J.N.W. offers a direct channel through which the High Command can pass down to the research scientists a request for development of any particular instrumentality which could be particularly effective in connexion with some contemplated operation. This

type of liaison between the scientists and the High Command is new in the United States. Its possibilities are still being explored and developed, but it can be said definitely that it has already demonstrated its possibilities of great value in the war. It is a move in a desirable direction in which you have gone further than we have gone.

National Inventors' Council. War is a great stimulus to invention, not only in the research laboratories of a country, but on the part of great numbers of its citizens, some of whom are technically competent and most of whom are uninformed but sincere in their desire to be helpful. Any actively operating research organization like the O.S.R.D. or the Naval Research Laboratory could be quickly bogged down under the deluge of ideas and inventions induced from all sources by the war. It is very important for purposes of morale that these inventors and would-be inventors be sympathetically handled. It is also important that their ideas be expertly examined to make sure that really worth-while ideas are not brushed aside, even though experience has shown that perhaps only one in one hundred thousand is new and significant.

To give such sympathetic and expert consideration and to screen the interesting suggestions out of the great mass, the National Inventors' Council was established in June 1940, in close association with the U.S. Patent Office in the Department of Commerce, under the chairmanship of Dr Charles F. Kettering, Vice-President in charge of research for the General Motors Corporation. All suggested inventions relating to the war from any source and submitted to any agency or person in the government are channelled through this National Inventors' Council (unless they happen to come initially to an appropriate agency which is immediately interested in pursuing the matter). They pass through the hands of an expert staff of examiners who select those inventions which appear to have merit and bring them to the attention of the appropriate agency.

Office of Production Research and Development of the War Production Board. Until recently the organized war research efforts in the United States failed to include the very important category of research aimed at the development of substitute materials in fields where shortages exist, or of improved methods of production and manufacture. It was apparently assumed that the commercial interest of the production companies would lead them automatically to take care of this situation. However, under the pressure of war-production orders, limitations of man-power and materials, and financial regulations, the normal peace-time incentives to such research and development work by companies proved inadequate to meet the needs of the situation. Consequently, last September, there was established in the War Production Board an Office of Production Research and Development under the directorship of Dr Harvey N. Davis, President of the Stevens Institute of Technology. This agency is still in the process of organization to operate somewhat along the lines of the Office of Scientific Research and Development but with primary responsibility for materials and method of production rather than for devices and instrumentalities of warfare. It is regrettable

that we did not have the foresight to establish this much-needed agency at a much earlier date, but it has already begun its operations and we hope that it may be enabled to play an important role during the balance of the war.

Engineering, Science and Management War Training Programme. Though not directly concerned with scientific research, a review of the scientific war agencies in the United States would not be complete without at least a brief reference to the efforts to increase the supply of technically trained personnel to meet the increasing demand for such personnel in every field of war activity. In October 1940 a special engineering training programme was organized under the U.S. Office of Education and financed by Congressional appropriation. Later, this programme was extended to include also training in science and industrial management. It operates at both the collegiate and the technical school levels, and its magnitude may be appreciated by the fact that, even in its first year of operation, it put through its specialized courses approximately ten times as many students as graduated in that year from the regularly established engineering colleges. Most but not all of the work was carried on in night schools, and the whole programme has been decidedly helpful in relieving the technical man-power shortage.

Army and Navy Technical Training Programmes. At the present time the Army and Navy are jointly establishing a very extensive programme for the training of their own younger personnel in such fields as aeronautical engineering, naval architecture, electronics, communications, automotive engineering, etc., through contractual arrangements with several hundred of the nation's colleges and universities. Under these programmes it is anticipated that approximately 250,000 selected young men in uniform will be detailed for this training at educational institutions during the coming year, the duration of such training to vary from field to field and individual to individual, in accordance with the needs of the situation and the performance of the individual. These special collegiate programmes are intended to supplement, at the higher level, the very much larger technical training programmes which the Army and Navy are conducting in their own establishments.

Conclusion

I conclude this factual, over-long, but I hope usefully informative address on a note of faith and optimism which I am sure is shared by the allied scientists on both sides of the Atlantic. Each of us concerned with some phase of the war effort is aware of some very significant new applications of scientific research in the war. For most of us, this knowledge is largely restricted to the special fields in which we ourselves have been working. Of necessity, the general public knows only in a vague way about some of these things and nothing at all about most of them.

When victory has been won, and the whole story of these scientific accomplishments can be told, it will indeed be a thrillingly interesting recital. Out of it all will come, not only its important contribution to victory, but a number of exceedingly significant results of permanent peace-time value. It is already evident that

many of these war-time developments will have very useful peace-time applications, whose contributions to our standards of living and general prosperity and comfort will help to compensate for the ravages wrought by the war. Scientists will have a renewed faith in the worth-whileness of their work, and will continue their intellectual and practical endeavours with the increased power that has come from the experience of 'team-work' on war problems. The general public, and especially the governmental and industrial leaders, will have greater appreciation of the value of science and scientists, both pure and applied—and this should result in permanently increased support of scientific research in the universities, industries and governmental agencies. These, I trust, will be some of the long-term gains to which we may look forward as the result of the temporary concentration upon practical problems of survival and victory which the war has forced upon us.

With these words of optimism, I close with the hope that the next American Pilgrim Trust lecturer to address you may not feel obliged to discuss the war, but will be able to treat of some interesting aspect of the progress of science in accord with the original conception of Sir William Bragg and as a happy feature in the post-war forward march of Science.

The secondary electron emission from metals in the low primary energy region

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This paper describes a new method and apparatus for measuring and analysing the secondary electron emission from non-gaseous materials. It has been devised especially for dealing with secondary emissions caused by primary electrons of very small energy. The essential features include a beam of primary electrons defined and controlled by an electrostatic electron lens system, which directs it towards the centre of a sphere A of the material investigated. A is surrounded by a concentric conducting sphere which collects the secondary electrons emitted from the surface of A. With the arrangement as set up it is possible to measure the contact potential difference between essential elements of the apparatus during the course of the experiments, without moving them or doing anything which would change the nature or composition of their surfaces.

The method is applied to the case of pure gas-free copper with primary electrons having energies down to the lowest practicable with a tungsten thermionic source (about 0·35 eV at 2000° K). The distribution of energy is analysed both for the primary and the secondary electrons. It is found to be practically the same for both groups for all energies below a few volts. From this we deduce (1) that for these low-energy electrons the secondary electrons are just reflected electrons, and (2) that the coefficient of reflexion r varies very little with the energy of the electrons. Numerous direct determinations of r have been made.

It is shown that no manipulation with fields can ever reduce the mean energy of electrons from a thermionic source below $2kT$, where T is the temperature of the source and k is Boltzmann's constant. Many determinations of r have been made from a few volts down to $2kT$, and the average value of r is about 0·24. No variation of r has been established with certainty, but there are indications that it drops a little from the value at $2kT$ to a minimum at about $2kT+0{\cdot}5$ eV, then increases slightly.